Synthetic Organic Chemicals

The Use of Organic Chemicals in Analytical Procedures

FOR many years the analytical chemist avoided by design or accident the general use of organic chemicals in his work. Some few he accepted as a matter of course and perhaps without much thought of their organic nature. In qualitative analysis he used chloroform as a solvent in testing for bromine and iodine. A few indicators were in common use, but organic chemicals were conspicuous by their absence from his laboratory shelves. Then came dimethylglyoxime, the first organic chemical of wide usage as a reagent for a metal.

Tschugaeff proposed the use of this compound for the analysis of nickel in 1905 (Z. anorg. chem. *46*, 144), and in the same year Busch (B. *38*, 861, *1905*) introduced nitron (diphenyl endoanilo dihydrotriazole), then the only known precipitant for the nitrate ion. Four years later ammonium nitrosophenylhydroxylamine was prepared by Bamberger and Baudisch (B. *42*, 3568, *1909*), and as "cupferron" was used by Baudisch in the analysis of copper and iron (Chem. Zeit. *33*, 1298, *1909*).

Since that time the use of organic compounds in analysis has been increasing rapidly, a trend which has been more noticeable within the last decade. Organic compounds are used in analytical procedures in four general ways:

1. *To produce color reactions due to the hydrogen ion.*
2. *To produce other color reactions.*
3. *As precipitating agents.*
4. *As solvents or as flotation media.*

Hydrogen Ion Indicators

Literature in the field of hydrogen ion determinations by change of color of organic compounds is very extensive. Perhaps the most beautiful result achieved in this field is, from the standpoint of the analyst, the division of the whole range of hydrogen ion concentrations into short sections, the boundaries of which are defined by the color changes of indicators of known composition.

Other Color Reactions

In the second group fall those color reactions which depend on oxidation and reduction, or on addition or condensation. The former have found extensive application, especially in biochemical analysis, principally because of the limited samples available or because of the small content in the sample of the element sought.

The reduction of phosphomolybdate to a colored compound by organic amines or hydroxylated compounds has, for instance, received considerable attention. As silicomolybdates act simi-

larly (Foulger, J.A.C.S. *49*, 434, *1927*), great care must be exercised to control the conditions of reduction so that silicon compounds do not interfere with the phosphomolybdate determination. Under strictly empirical conditions, the method is quantitative (Fiske and Subbarow, J. Biol. Chem. *66*, 387, *1925*).

A qualitative test for iron (Andreasch, B. *12*, 1390, *1879*) recently reintroduced and made quantitative (Lyons, J.A.C.S. *49*, 1916, *1927*) depends on the ability of thioglycollic acid to reduce ferric to ferrous salts. In the presence of ammonia, the ferrous salts combine with excess of the reagent to form a reddish purple color which is more intense than that given by thiocyanate. The reagent is indifferent to the state of oxidation of the salt and is said to be capable of detecting one part of iron in ten million.

In the detection and estimation of nitrous acid in exceedingly small amounts, advantage is taken of its ability to diazotize an organic primary amine which is subsequently coupled to form a dye. The depth of color of the solution measures the nitrous acid originally present (Moir, Jour. S. African Assoc. Anal. Chem. *4*, 3, *1921*). Alternatively, one part of nitrous acid in 100,000 may be detected and determined by the formation of nitrosodimethylaniline (Miller, Analyst *37*, 345, *1912*).

Precipitating Agents

Among the precipitating reagents, mention has already been made of dimethylglyoxime, nitron, and cupferron. Perhaps one of the most important of the newer reagents is α-benzoinoxime, which, in acid solution, is apparently specific for molybdenum, provided any vanadium or chromium which might be present is in the reduced condition (Knowles, Bur. Standards Jour. Res. *9*, 1, *1932*). Another organic precipitant that has received much study in recent years is 8-hydroxyquinoline. It forms

insoluble salts with a number of metals, although at the present time it is used principally for the determination of aluminum and magnesium.

The list of organic compounds which are of value for the analysis of metallic salts has been greatly increased and is being constantly extended. It now includes reagents for aluminum, beryllium, bismuth, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, mercury, nickel, sodium, titanium, zinc, zirconium, and many others. "Organic Reagents for Metals" by Hopkins and Williams gives several procedures, and a very complete bibliography.

Solvents or Flotation Media

The use of organic liquids as solvents for the separation of many organic from inorganic constituents of mixtures is obvious. It sometimes happens that in a mixture of inorganic salts, one constituent may have a much higher solubility in an organic solvent than the other. In such a case, separation may also be affected. A variation of this procedure, which finds important use in analysis, is that for the separation of mixtures of salts into their constituents by the use of organic nonsolvents of varying specific gravities. In this way it has been possible to obtain a more probable analysis of salt mixtures than would result from the application of standard procedures, especially if the ions of the mixture react in aqueous solution.

Lundell (Ind. and Eng. Chem. Anal. Ed. *5*, 223, *1933*) aptly pointed out: "We have gone about as far as we can go along the old paths. Worthwhile developments must come as the result of new methods of attack such as the utilization of complex ions or systematic study of reactions of organic compounds." The results already obtained in the application of organic compounds to analytical procedures augur well for greater achievements in the future.

Preparation and Reactions of Ketenes

KETENES, discovered by Staudinger in 1905, have the general structure $R_2C:C:O$. Although this structure would seem to imply properties of olefins and ketones, this is not the case—the double bond is made extremely active by the presence of the carbonyl group, so that it shows reactivities far beyond those of a normal unsaturation. The carbonyl group gives none of the usual tests for ketones.
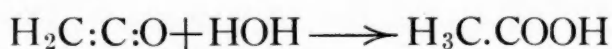
Ketene, the parent substance, is a colorless, poisonous gas, boiling at $-56°$, having a sharp, choking odor. Most of the substituted ketenes are liquids at ordinary temperature. Carbon suboxide, $O:C:C:C:O$, formed by heating malonic acid or its ethyl ester with phosphorous pentoxide, is also a ketene, and is an anhydride of malonic acid in the same sense that ketene is an internal anhydride of acetic acid.

Staudinger classified ketenes as keto-ketenes or aldoketenes, depending upon whether or not both hydrogen atoms were replaced by organic radicals. The aldoketenes, including ketene itself and carbon suboxide, are colorless, incapable of autoxidation, and are polymerized by pyridine. The ketoketenes are colored, readily capable of autoxidation, and form additive compounds with tertiary amines, such as pyridine, quinoline, and acridine; also, with substances containing the groupings $C:N$ and $C:O$, such as Schiff's bases and quinones. Ketoketenes polymerize on standing, but far less readily than aldoketenes.
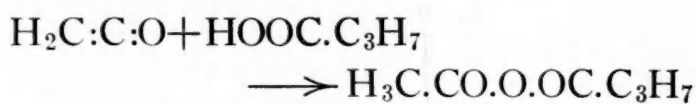
The general method for preparing ketenes is the reaction of zinc with alpha-halogenated acid halides. Thus alpha-bromoisobutyryl bromide in ether solution with zinc gives dimethyl ketene. Ketene itself, however, is best prepared by the pyrolysis of acetone, though it is also obtained similarly from ethyl acetate, acetic acid, or acetic anhydride.

On a small scale a glowing platinum wire may be used. For larger amounts, acetone vapor is passed through a combustion tube filled with clay chips heated to 700° C. Ketene is formed in about 40% yield, along with methane and a number of by-products: $CH_3.CO.CH_3 \rightarrow CH_4 + CH_2:C:O$. In commercial practice the tubes may be filled with metal, such as copper turnings, or a catalyst, such as aluminum sulfate.
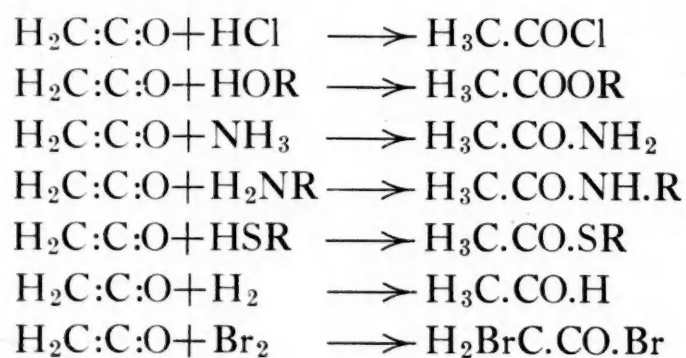
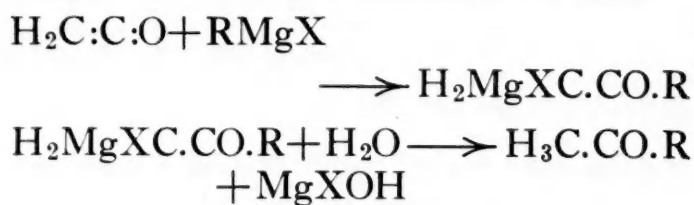Ketene reacts with a wide variety of compounds. It adds water, regenerating acetic acid:

$$H_2C:C:O + HOH \longrightarrow H_3C.COOH$$

The action of ketene on organic acids results in anhydride formation. This reaction affords a good method for preparing mixed anhydrides:

$$H_2C:C:O + HOOC.C_3H_7$$
$$\longrightarrow H_3C.CO.O.OC.C_3H_7$$

Ketene behaves analogously in many instances to form an acid chloride, ester, amide, thioester, aldehyde, or substituted acid halide, as shown by the following equations:
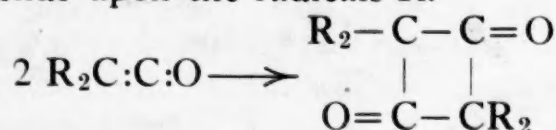
$$H_2C:C:O + HCl \longrightarrow H_3C.COCl$$
$$H_2C:C:O + HOR \longrightarrow H_3C.COOR$$
$$H_2C:C:O + NH_3 \longrightarrow H_3C.CO.NH_2$$
$$H_2C:C:O + H_2NR \longrightarrow H_3C.CO.NH.R$$
$$H_2C:C:O + HSR \longrightarrow H_3C.CO.SR$$
$$H_2C:C:O + H_2 \longrightarrow H_3C.CO.H$$
$$H_2C:C:O + Br_2 \longrightarrow H_2BrC.CO.Br$$

Upon hydrolysis of the product formed by the addition of the Grignard reagent to ketene, a ketone is formed.

$$H_2C:C:O + RMgX$$
$$\longrightarrow H_2MgXC.CO.R$$
$$H_2MgXC.CO.R + H_2O \longrightarrow H_3C.CO.R + MgXOH$$

Spontaneous polymerization of ketenes results in

cyclobutane derivatives, whose stability depends upon the radicals R.

$$2\ R_2C{:}C{:}O \longrightarrow \begin{matrix} R_2-C-C=O \\ |\qquad| \\ O=C-CR_2 \end{matrix}$$

With oxygen, ketoketenes in ether solution form peroxides, which decompose in ethereal solution into ketones and carbon dioxide, or explode violently when dry. Ketene oxides are formed in the same way.

Ketenes also react with certain unsaturated substances to form ring compounds, many of which are not stable, and may break up to regenerate the original materials or new compounds.

Eastman Organic Chemicals as Analytical Reagents

XXXI Titanium and Molybdenum

Cupferron

T. R. Cunningham, Ind. & Eng. Chem. (Anal. Ed.) *5*, 305 (1933)

Titanium in high-chromium and chromium-nickel steels may be separated by precipitation with cupferron. The drillings are dissolved in warm, dilute sulfuric acid which is later cooled to room temperature. Ashless paper pulp is added and a cold, freshly prepared 6% solution of cupferron dropped in carefully with stirring until the precipitate turns to a reddish brown color. The precipitate is then filtered, and washed with cold, dilute sulfuric acid and with dilute ammonia. After igniting at a low temperature, the crucible contents are fused with potassium pyrosulfate. The melt is then dissolved, and the titanium determined colorimetrically.

Alpha-Benzoin Oxime

H. B. Knowles, Bureau of Standards Jnl. of Research *9*, 1 (1932)

Molybdenum is precipitated quantitatively by alpha-benzoin oxime and may be separated from copper, lead, bismuth, tin, arsenic, antimony, iron, titanium, chromium, and vanadium. The steel sample is dissolved in dilute sulfuric acid and a small amount of nitric acid added to complete oxidation. The clear solution is treated with sulfurous acid or ferrous ammonium sulfate to reduce vanadic and chromic acids if present. A 2% alcoholic solution of the reagent is added, followed by bromine water, and then a little more of the 2% reagent. The precipitate is washed with a dilute sulfuric acid solution, ignited to the oxide, and weighed.

New Eastman Organic Chemicals

3128	Ethyl 4-Nitrophthalate BP 208-210°/15 mm.	100 g.	$ 9.00 C
3585	Di-n-propylaminobenzaldehyde BP 204-206°/20 mm.	10 g.	2.00 A
3586	Ethyl m-Nitrocinnamate MP 74-76°	100 g.	11.00 C
P 3022	Tetraethylammonium Chloride (Practical)	100 g.	6.00 C
P 3592	Tetramethylammonium Chloride (Practical)	100 g.	8.00 C
3594	*l*-Hydroxyproline	1 g.	2.00 O
3520	Tolu-p-quinone MP 65-67°	100 g.	6.00 C
3555	Dicetyl MP 68-69.5°	10 g.	4.00 A
3571	Ethylene Thiocyanate MP 88-90°	100 g.	10.00 C
3514	5-Diazouracil	10 g.	6.00 A
3581	p-Nitrocinnamic Acid MP 285-287°	10 g.	2.50 A
3591	Ethyl o-Nitrocinnamate MP 41-43°	100 g.	18.00 C